



## NOTE

# Terrestrial camera traps: essential tool for the detection and future monitoring of the Critically Endangered Sira curassow *Pauxi koepckeae*

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**ABSTRACT:** The only known population of Sira curassow *Pauxi koepckeae* resides within the Sira Communal Reserve, a chain of isolated and high-elevation outcrops of the Peruvian Andes. The species has previously been detected on just a handful of occasions, is thought to number less than 400 adult individuals and is Critically Endangered according to the International Union for Conservation of Nature Red List. As such, evaluating potential monitoring techniques to study the Sira curassow is of crucial importance to best inform future management strategies. We performed a preliminary assessment of camera traps to detect and collect novel ecological information on the Sira curassow. We used 17 cameras placed at regular altitudinal intervals (either 50 or 100 m) between 800 and 1800 m above sea level, 2 cameras placed at important habitat features, and 2 additional cameras placed on trails to assess hunting activity. Cameras were left *in situ* for 6 mo (March–September 2015). Sira curassows were detected at 26% of survey locations, totalling 19 independent detections. This resulted in an overall occupancy estimate of 0.25 across the whole transect and 0.55 across the current known elevational range. All records occurred between 1150 and 1500 m. Finally, we detail new ecological information obtained from the camera trap footage, re-address current threats to the species and provide recommendations regarding future monitoring.

**KEY WORDS:** Cracid · Range · Juvenile · Population · Trail camera · Cryptic · Elevation

## INTRODUCTION

The isolated upper reaches of mountain ranges are known to harbour a host of range-restricted endemic species not found at lower elevations (Myers et al. 2000). Such high-elevation endemics are thought to be under a disproportional risk from anthropogenic-induced climatic shifts, which will likely act to reduce the availability of suitable habitat and threaten small

populations (Dirnböck et al. 2011). While there is awareness of the greater threat to high-elevation endemics, studying them is often hindered by their existence in remote locations with poor local infrastructure and harsh terrain. Consequently, the ecology, natural history and population trend of a given species can be difficult to determine, let alone monitor for prolonged periods (Ríos et al. 2005). A clear example of the paucity of information on high-

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elevation endemics is the case of the Sira curassow *Pauxi koepckeae*, a recently described member of the cracid family, the most threatened family of birds in the Americas (Brooks et al. 2006). The Sira curassow is endemic to the Cerros del Sira in central Peru (Gastañaga et al. 2007) and Critically Endangered according to the International Union for Conservation of Nature (IUCN) Red List (IUCN 2014).

Previous work on the Sira curassow has estimated the population density to be less than 1 adult ind. km<sup>-2</sup> (Gastañaga et al. 2011), which suggests that the total population size is lower than 400 adult individuals across its current known range (Gastañaga et al. 2007). However, the species has been visually detected on only a handful of occasions by those who have sought to study it, making accurate estimates of population size difficult to determine. While traditional survey techniques such as visual encounter and audio transects were essential for the rediscovery of this species in 2005 (after 36 yr being undetected; Gastañaga et al. 2007), such techniques have been notoriously unproductive (Mee et al. 2002, Gastañaga 2006, Gastañaga et al. 2007, 2011, Socolar et al. 2013). For example, Gastañaga et al. (2007) reported that in 3 visits to the region between 2004 and 2005, they directly observed just 3 individuals. The paucity of records of the Sira curassow is particularly concerning given its highly restricted range and due to pressure from local subsistence hunting (Socolar et al. 2013). Given the low encounter rates using traditional techniques and the Critically Endangered status of the species, different methodologies must be investigated to provide up-to-date and accurate conservation recommendations.

One potential method for rapid assessments and monitoring of the Sira curassow (and other medium-large vertebrate fauna located in remote regions) is the deployment of camera traps (O'Brien & Kinnaird 2008, O'Connell et al. 2010). Camera traps have been used previously to detail the population size, population trends, behaviour and ecology of a variety of different bird species (O'Brien & Kinnaird 2008) and have already been successfully utilised to study other endangered members of the cracid family (e.g. Alves et al. 2015). As such, camera-trapping methodologies have the potential to elucidate novel and otherwise hard-to-obtain information in the case of the Critically Endangered Sira curassow. However, to date, their utility has not been assessed.

We deployed 17 terrestrial camera traps across an elevational gradient and 2 camera traps at key habitat features along a previously unsurveyed ridge within the Sira Communal Reserve. Specifically we

aimed to (1) assess whether terrestrial trail cameras are an effective methodology to detect the Critically Endangered Sira curassow; (2) investigate whether cameras can provide important information on the species' ecology, life history and conservation status; and (3) determine the presence of hunting activity within the study site.

## MATERIALS AND METHODS

### Study site

The Sira Communal Reserve encompasses the Cerros del Sira, a remote high-elevation outcrop situated near the eastern slope of the Peruvian Andes (Fig. 1A). The Cerros del Sira is isolated from the main Andean chain by the Río Pachitea and a broad swathe of lowland forests, large areas of which have been deforested and converted to pasture (Fig. 1B; Finer et al. 2016). The upper reaches of the Cerros del Sira reach to 2400 m above sea level (a.s.l.) (Weske & Terborgh 1971) and contain both lower and upper montane forest environments and elfin cloud forest towards the highest elevations (Forero-Medina et al. 2011, Socolar et al. 2013). Nineteen survey locations were situated along a previously unstudied ridge on the northwestern border of the Sira Communal Reserve (specific coordinates available upon request to the authors). The ridge is situated 5 km to the west of the current distribution map of the Sira curassow, as provided by the IUCN Red List (IUCN 2014).

### Camera trapping

We deployed 21 terrestrial camera traps triggered by a motion detector (17 Bushnell Trophy Cam 119636 and 4 Bushnell Trophy Cam HD 119676) across the elevational gradient, 19 for the detection of Sira curassows and 2 to monitor hunting activity within the area. Cameras were all set at a height of between 20 and 40 cm, a height appropriate for the detection of other cracids (Thornton et al. 2012), with the 2 m directly in front of the cameras cleared of all ground-level vegetation. Camera traps were programmed to work 24 h d<sup>-1</sup> and to take a 14 s video each time the traps were triggered, with a minimum interval of 30 s between successive video triggers. The choice of video length and interval were chosen as a compromise to maximise battery life across the 6 mo period while having a video of sufficient length to observe behaviour and successfully identify spe-

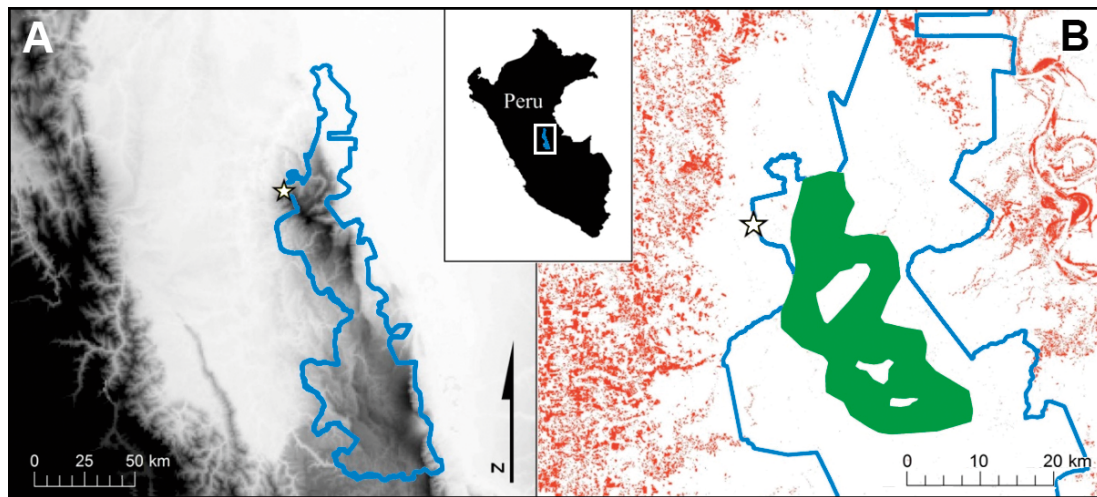


Fig. 1. Inset shows the location of the Sira Communal Reserve in Peru. (A) Elevational gradient from high-elevation areas (black = >2000 m above sea level [a.s.l.]) to low-lying areas (white = 250 m a.s.l.); the Sira Communal Reserve outline shown in blue; star denotes approximate location of the ridgeline surveyed in this study. (B) Currently known distribution of the Sira curassow according to the International Union for Conservation of Nature (IUCN 2014; indicated by the filled green polygon) and canopy loss in the surrounding region from 2004 to 2015 (red dots; source data taken from Hansen et al. 2013)

cies. Date and time were automatically stamped on all videos. Traps were set up in mid-March 2015 and removed at the beginning of September 2015. This time period coincides with the dry season in this region to reduce water-related camera malfunctions and to safely access the study site (high rivers make the area impassable during the rainy season). Of the 19 curassow monitoring cameras, 13 were placed at intervals of 50 m altitude between 800 and 1400 m a.s.l. (mean horizontal distance between traps = 225 m; SD = 107 m), 4 were placed at 100 m intervals in altitude between 1400 and 1800 m a.s.l. (mean horizontal distance between traps = 177 m; see Fig. 2, represented by circles), and 2 were placed in locations deemed to be important water sources during the dry season (a clay lick at 1056 m a.s.l. and a stream at 1215 m a.s.l.; Fig. 2, represented by triangles). Two additional cameras were located at the only entry point to the ridgeline (865 m a.s.l.) and at our principal campsite to monitor hunting activity in our absence (Fig. 2, represented by crosses). Survey sites were only visited twice, for camera setup and takedown, to minimise disturbance effects.

Not all cameras worked for the entirety of the study period: of the 19

curassow monitoring cameras, 13 functioned for the full duration (average camera days =  $175.7 \pm 4.8$ ) and 6 malfunctioned beforehand (average camera nights =  $89.8 \pm 51.4$ ). In total, this resulted in 2823 camera trap days. Although cameras placed at 1700 and 1800 m elevation were active for the majority of the study, each was spun by an Andean bear *Tremarctos ornatus*, after 11 and 44 d, respectively, into direc-

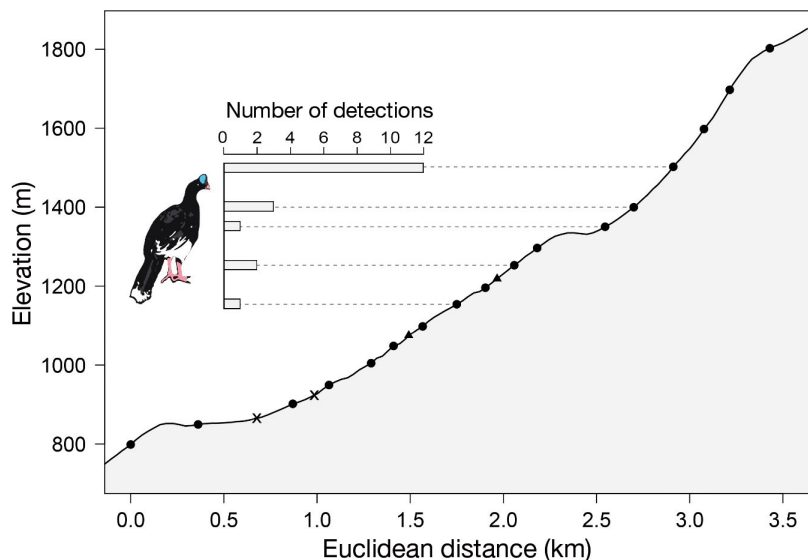


Fig. 2. Survey locations and number of independent detections of the Sira curassow. Cameras placed on trails (●) at specific habitat features (▲), to monitor anthropogenic hunting activity (×). Dashed lines link Sira curassow detection with the corresponding altitude and camera trap

tions unlikely to detect *Sira curassows* (dense vegetation). The lack of detections above 1600 m should therefore be treated with caution. Both camera traps set to monitor hunting activity worked for the full duration of the study. Detections of *Sira curassows* on the same camera were considered independent if there was an interval of >60 min between triggers, a conservative estimate double that used by other authors (e.g. Day et al. 2016).

As the camera trapping was performed on a single elevational gradient, we conducted a single-season occupancy analysis (MacKenzie et al. 2002), separating the 6 mo sampling session into three 2 mo sampling blocks. We assumed a constant proportion of occupancy and constant detection probability rather than using a multi-season modelling strategy. Occupancy estimates were derived using the 'unmarked' package (Fiske & Chandler 2011) in the R statistical environment.

### Incidental surveys

While survey team members were present on the elevational transect (6 March until 24 March 2016), all incidental audio and visual detections of *Sira curassows* were recorded. The time spent on the ridgeline was not solely spent on camera trap setup: herpetofaunal surveys, mist netting and trail clearing were also carried out. Incidental *Sira curassow* records were confirmed both with video footage and with audio recordings using a Zoom H2n recorder.

## RESULTS

In total, *Sira curassows* were detected on the camera traps on 30 occasions, 19 of which were classified as independent observations across 18 separate days. Of the 19 camera traps deployed, 5 detected *Sira curassows*. All detections occurred between 1150 and 1500 m a.s.l. (Fig. 2). Estimated habitat occupancy was 25.1% (compared with 23% naïve observed occupancy) across the whole transect and 55.3% (compared with 50% naïve observed occupancy) within the known elevational range (1100 to 1700 m a.s.l.) of the *Sira curassow*. The detec-

tion probability from the occupancy model was estimated to be 0.54.

Raw detections increased with elevation (from 1150 to 1500 m) then ceased entirely (Fig. 2). However, the lack of detections at 1700 and 1800 m a.s.l. should be treated with caution, as the cameras were only active for 11 and 44 d, respectively. In comparison, *Sira curassows* were only detected incidentally on 3 independent occasions on 2 separate days. The first 2 were audio observations which occurred on 9 March at 1250 and 1150 m a.s.l.; however, for both instances, the calls were too faint to record. The third visual observation occurred on 11 March at 1130 m a.s.l. and resulted in 1 video and 2 audio recordings (audio deposited with Xeno-Canto: [www.xeno-canto.org](http://www.xeno-canto.org); XC302848; XC302846).

Weekly detection frequency derived from camera trap detections across all locations varied between 0 and 2 (mean = 0.76; SD = 0.86; Fig. 3A), including a complete lack of detections in the final 6 wk of the study. Daily activity was strictly diurnal, with activity peaking in the afternoon (Fig. 3B). Of the 19 independent detections, 18 were of the more common black morphotype (Fig. 4A), while 1 was of the rarely encountered brown-barred morphotype (Fig. 4B; see also Socolar et al. 2013). On 19 June 2015, a video captured an adult individual being followed by a juvenile without clear signs of a blue crest (Fig. 4C).

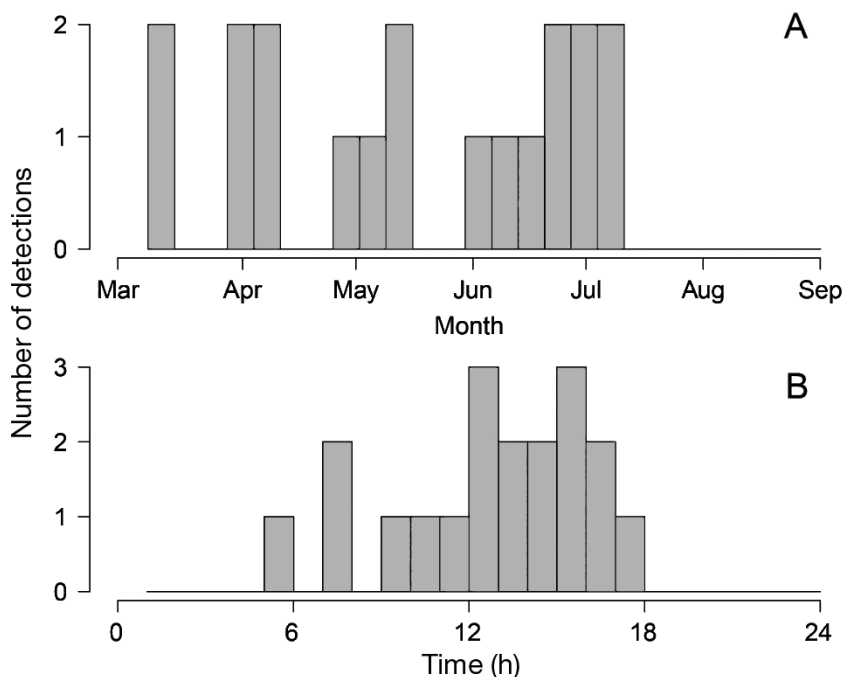


Fig. 3. *Sira curassow* activity patterns. (A) Independent detections per week across the study period; (B) daily activity pattern





Fig. 4. Representative footage of the Sira curassow. (A) Individual in adult plumage; (B) previously unphotographed brown morphotype; (C) adult (right) with a juvenile (left); (D) hunter in possession of a razor-billed curassow

This video represents the only time 2 individuals were encountered at the same time and is to our knowledge the first time a juvenile individual had been observed in the wild.

Finally, the 2 cameras set specifically to monitor human presence within the study site captured human activity on 7 different occasions; on 3 of these occasions, the individuals appeared to be engaging specifically in hunting activities (where clear evidence of possession of a gun or killed game was visible; e.g. Fig. 4D). On only 1 of these occasions did the hunting activity appear to be successful, resulting in the shooting of a razor-billed curassow *Mitu tuberosum*, a co-occurring member of the cracid family with an elevational range overlapping with that of the Sira curassow (see the Appendix).

## DISCUSSION

This work shows that camera traps are an essential tool for the detection of the Sira curassow *Pauxi koepckeae*. In just 6 mo of camera trapping (2823 camera trap days or ~30 d of field time to set up and take down cameras), we accrued 19 independent detections of this Critically Endangered and rarely observed cracid species. Prior to the completion of this work, only 2 photographs were available of this species in the public domain, and 1 video existed in a private collection (Gastañaga et al. 2007). Our study also provides video footage of an even rarer barred morph, and a juvenile for the first time, and highlights the continued potential threat of hunting to the persistence of the Sira curassow.

Camera traps only detected *Sira curassows* between 1150 and 1500 m a.s.l., which is consistent with the current known elevational range for the species (previous work has detected the species up to 1685 m; Socolar et al. 2013). Although our initial estimates of occupancy were calculated from a relatively small data set, along a single transect and within a single year, these estimates serve as a baseline for future surveys. More robust and extensive surveys could generate estimates across a number of transects, seasons and years and serve as a powerful tool to quantitatively assess changes in detection probability and occupancy of the *Sira curassow*. The number of independent detections using camera traps (19) was substantially higher than that from both audio (2) and visual incidental records (1). This difference derives from the fact that camera traps have the substantial advantage of remaining *in situ* for prolonged periods of time (in this case, 6 mo). In fact, the cameras in this study likely equate to the total number of visual records obtained by all previous expeditions intending to detect the species, if not superseding them.

As 5 of the 10 camera traps within the known elevational range detected *Sira curassows* within the survey period, researchers using just 4 camera traps (within the range 1100 to 1700 m a.s.l.) for 6 mo have close to a 95 % probability (93.8 %) of detecting a *Sira curassow*. Whether this detection probability generalises across the whole species' range, or between seasons, remains to be determined. While the deployment height of 20 to 40 cm meant Andean bears interfered with 2 camera setups, we are reluctant to suggest raising camera trap height, as recent research has shown that this has the potential to reduce detection probabilities (Meek et al. 2016). Researchers looking to use camera traps in this region should explore whether this is also the case for the *Sira curassow* and investigate more robust methods of securing the cameras (such as bear-proof housings).

There appeared to be no strong trend in the number of raw detections across the study period. However, no curassow detections occurred in the final 6 wk of camera trapping. Further survey effort is required to determine if this represents a seasonal shift in detection probability of this species. Daily activity patterns suggest that the *Sira curassow* appears strictly diurnal, with ground-based foraging behaviour peaking in the afternoon. Despite detecting razor-billed curassows at the 2 sites deemed to be important habitat features (the clay lick and stream; Appendix), no *Sira curassow* detections occurred at

either site, but owing to such a small sample size, it is difficult to determine whether or not *Sira curassows* use such habitat features. A breeding event of the *Sira curassow* was also recorded for the first time: 1 adult and 1 large juvenile offspring were detected in the same video. The presence of just 1 juvenile may indicate a low reproductive rate for this species, which is consistent with that of other large cracids (Brooks et al. 2006). They typically lay 1 or 2 eggs and have a slow maturation period of at least 3 yr (Brooks et al. 2006). This pair also represented the only video where more than 1 individual was captured, which suggests that the *Sira curassow* is less social than the co-occurring razor-billed curassow (where multiple individuals are commonly detected) or that sociality may be density dependent in this species.

We recorded 7 instances of human activity along the elevational transect, 3 of which appeared directly related to hunting. Given the strong overlap between razor-billed curassow and *Sira curassow* elevational distributions, and the fact that we detected a hunter with a razor-billed curassow carcass during the study period (Fig. 4D), the likelihood of hunters coming into contact with *Sira curassows* is high, despite past research suggesting that this might not have previously been a considerable threat (Mee 2001). Our evidence supports previous work where local communities self-reported hunting of *Sira curassows* in the past (Gastañaga et al. 2007). Although conservation actions and questionnaires to raise awareness of its unique status have been implemented in communities around Cerros del Sira (Gastañaga et al. 2007), we believe that hunting is still an important potential threat to the persistence of this species. The non-hunting human activity we recorded likely arose as the community living adjacent to the survey location is directly involved in commercial logging (currently no higher than 900 m a.s.l.). Although logging does not currently appear to be encroaching on the known range of the *Sira curassow* (at least in this locality), there is considerable potential for it to do so in the future. It is apparent from Fig. 1B that although most deforestation has occurred outside of the reserve's core area, a significant amount of canopy loss has been detected in the northern, lower-lying areas within the reserve border. This raises the question as to whether the level of protection currently provided by the reserve is sufficient, as it appears that only altitude has prevented deforestation from the core zone. As surrounding forest is lost and anthropogenic pressure increases, local inhabitants will likely be driven to higher elevations to access natural re-

sources. Such activity will likely be in direct conflict with the curassow's future survival.

While we have demonstrated the utility of camera traps to detect Sira curassows, we were not able to identify unique individuals owing to the low resolution of the video footage. We recommend future studies use high-definition (HD) cameras to assess the viability of individual identification. Reliable identification of individuals could ultimately result in the determination of density estimates. The use of HD cameras could also facilitate the identification of an individual's sex from the size and shape of the blue casque (as for the helmeted curassow; Naveda-Rodríguez & Strahl 2006), which would result in more accurate population size estimates (see Alves et al. 2015). Should identification of unique individuals prove impossible, researchers looking to perform robust population monitoring should adopt an occupancy modelling approach (such as that employed here), where the observation of marked individuals is not required (O'Brien & Kinnaird 2008). Such an approach would facilitate robust distribution estimates throughout the species' range, provide a surrogate for population density, and facilitate the quantitative assessment of factors thought to be influencing the detection probability and occupancy of this species (such as hunting, temperature and forest structure). Accurate estimates of population size and density will be particularly important to address Sira curassow population responses to climate change. Previous research has already detected an upward range shift of 49 m over a 41 yr interval for several bird species in the region (Forero-Medina et al. 2011). Such shifts in range could be catastrophic for the remaining Sira curassow population, as any upward shift in elevational distribution will reduce the amount of habitat available to the extant population. Without the appropriate tools to effectively monitor both range and population changes of the Sira curassow, we will be unable to mitigate any declines in abundance or distribution with targeted conservation actions.

## SUMMARY AND FUTURE PERSPECTIVES

Traditional survey techniques such as audio and visual surveys have proven invaluable for the rediscovery and confirmation of the presence of the Sira curassow to date (e.g. Gastañaga et al. 2007). However, this work demonstrates that terrestrial camera traps also represent an essential tool to generate robust and reliable estimates of population size, den-

sity and distribution for this Critically Endangered species, especially when coupled with mark-recapture or occupancy modelling approaches. The ability to leave camera traps *in situ* for prolonged periods gives them a clear advantage over traditional methodologies, particularly where the terrain to be surveyed is remote and difficult to access. Expansion of the current survey area, multiple-year surveys across different seasons, use of HD-quality camera traps and adoption of robust analysis techniques will considerably improve our understanding of the threats facing the persistence of the Sira curassow.

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## Appendix

Detection summaries for Sira curassow and razor-billed curassow. P/A: presence (x) or absence (-); No.: number of independent detections; per day: number of detections on days when the camera was active

| Elevation (m) | Sira curassow |     |         | Razor-billed curassow |     |         |
|---------------|---------------|-----|---------|-----------------------|-----|---------|
|               | P/A           | No. | Per day | P/A                   | No. | Per day |
| 800           | –             |     |         | x                     | 3   | 0.02    |
| 850           | –             |     |         | –                     |     |         |
| 900           | –             |     |         | x                     | 2   | 0.01    |
| 950           | –             |     |         | –                     |     |         |
| 1000          | –             |     |         | –                     |     |         |
| 1050          | –             |     |         | –                     |     |         |
| 1056          | –             |     |         | x                     | 1   | 0.01    |
| 1100          | –             |     |         | x                     | 1   | 0.01    |
| 1150          | x             | 1   | 0.01    | x                     | 1   | 0.01    |
| 1200          | –             |     |         | x                     | 1   | 0.01    |
| 1215          | –             |     |         | x                     | 4   | 0.06    |
| 1250          | x             | 2   | 0.01    | x                     | 2   | 0.01    |
| 1300          | –             |     |         | x                     | 3   | 0.04    |
| 1350          | x             | 1   | 0.11    | –                     |     |         |
| 1400          | x             | 3   | 0.02    | –                     |     |         |
| 1500          | x             | 12  | 0.07    | –                     |     |         |
| 1600          | –             |     |         | –                     |     |         |
| 1700          | –             |     |         | –                     |     |         |
| 1800          | –             |     |         | –                     |     |         |